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3D strength distribution in the European lithosphere

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Tectonic studies made in intraplate Europe have shown that this area is more active than would be expected from its location far away from any plate boundaries, being characterized by horizontal and vertical motions with deformation rates of the order of 1-2 mm/yr and by diffuse seismicity, with earthquake magnitudes rarely exceeding 4.0, that can be attributed to the existence of old zones of weakness, which are re-activated under the current stress field. The construction of the very first 3D strength cube of the European lithosphere lead to a significant understanding of the dynamics of intra-lithospheric deformation processes. The identification of intraplate areas that are mechanically weaker or stronger than neighbouring areas helps to understand the observed spatial variation in the response of the European lithosphere to large scale plate tectonic and thermal loading. Moreover, the 3D strength cube allows to analyse the variation of rock strength with depth in two and three dimensions. In this way, is possible to identify the area where the crust is mechanically decoupled from the underlying subcrustal lithosphere.

Strength distributions of the lithosphere depend primarily on its thermal and compositional structure and are particularly sensitive to thermal uncertainties. In particular, the strength of continental lithosphere is controlled by its depth-dependent rheological structure in which the thickness and composition of the crust, the thickness of the mantle–lithosphere, the potential temperature of the asthenosphere, the presence or absence of fluids and strain rates play a dominant role. Differently, the strength of oceanic lithosphere depends on its thermal regime, which controls its essentially age-dependent thickness.

The 3D strength model is constructed using a first order 3D geometrical model of Europe's lithosphere and consists of several regions, representing areas of different composition, tectonic and/or thermal history. For continental realms, a 3D multi-layer compositional model are constructed, consisting of one mantle layer, two crustal layers and an overlying sedimentary cover layer, whereas for oceanic areas a one-layer model is adopted. The depth of the different interfaces several regional or European-scale compilations are distinguished on the base of deep seismic reflection and refraction or surface wave dispersion studies. The base of the crust is detected using a recently compiled European Moho map. More constraints on the thermal lithospheric structure are obtained from heat flow studies and upper mantle seismic tomography. This model is developed in two principal steps: 1) construction of a 3D compositional model and 2) calculating a 3D thermal cube The final 3D strength cube is obtained by calculating 1D strength envelopes for each lattice point (x,y) of a regular grid covering Europe. For each lattice-point the appropriate input values are obtained from the 3D compositional and thermal cube. A geological and geophysical geographic GIS database is used as reference for the construction of the input model.

The first results show that the European lithosphere is characterized by major spatial mechanical strength variations, with a pronounced contrast between the strong lithosphere of the East-European Platform east of the Tesseyre-Tornquist line and the relatively weak lithosphere of Western Europe. Within the Alpine foreland, pronounced north-west-southeast trending weak zones are recognized that coincide with major structures, such as the Rhine Rift System and the North Danish-Polish Trough, that are separated by the high strength North German Basin. Moreover, a broad zone of weak lithosphere characterizes the Massif Central and surrounding areas. A pronounced contrast in strength can also be noticed between the strong Adriatic indenter and the weak Pannonian Basin area and between the Fennoscandia, characterized by a relatively high strength, and the North Sea rift system corresponding to a zone of weakened lithosphere.

These results are validated not only with geological and geophysical data, but also with GPS data, which are used to reconstruct the strain rate field in Europe.